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Impact of climate change on maize productivity

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Abstract
Climate change poses a threat to the sustainable development despite rapid urbanization, the majority of population is dependent on agriculture and will remain vulnerable to climate shocks. Maize is grown by millions of farmers. Drought is one of the most detrimental abiotic stresses across the world which is seriously hampering the productivity of agric ultural crops. Maize is among the leading cereal crops in world, but it is sensitive to drought. Maize is affected by drought at different growth stage s in different regions. Germi nation potential, seedling growth, seedling stand establishment, overall growth and develop ment, pollen development, silk development, anthesis– silking interval, pollination, embryo development, endosperm development, and kernel development are the events in the life of maize crop which are seriously hampered by drought stress. It is vulnerable to heat as well, each degree increase in day where the temperature exceeds 30degree celcius reduces the final yield of maize by 1.7% under drought (Mayer *et al.* 2014).

Keywords: Climate change, drought, heat, ASI

Introduction
Most of climate changes are attributed to very small variations in earth's orbit that change the amount of solar radiations coming to our planet (Anonymous 2014). Besides these natural periodic changes in climate, it has been observed that anthropogenic activities plays substantial role in recent climate change. Enzel (2013) quoted in his research article that Svante Arrhenius (1859-1927), Swedish scientist, was the first to claim in 1896 that fuel combustion may eventually result in enhanced global warming. He proposed a relation between atmospheric carbon dioxide concentrations and temperature. He found that the average surface temperature of earth is about 15 degree celcius because of the infrared absorption capacity of water vapour and carbon dioxide. This is called natural green-house effect.

Arehenius suggested a doubling of the Co2 concentration would lead to a 5 degree temperature rise. He and Thomas Chamberlin calculated that human activities could warm the earth by adding Co2 to atmosphere. Climate change impacts society and ecosystems in a broad variety of ways for example change in climate can increase or decrease rainfall, influence agriculture crop yields, affect human, cause changes to forests and other ecosystems, or even impacts our energy supply. Climate change is seen as the main threat to agriculture sector over the globe; as vulnerable of this sector is high and adaptation measures are restricted by the limited availability of resources (Mendelsohn and Dinar, 1999; AL-Bakri *et al*. 2010) [132, 29]. The vulnerability of the agriculture sector of both climate change and variability is well established.

Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time i.e. decades to million years. While speaking at the natural Farming summit hosted by the sri sri institute of Agriculture Sciences and Technology Trust (SSIAT) in bengaluru from may 9_10, B. Venkateshwarlu former director at International Central Research Institute for dry land Agriculture (CRIDA), Hyderabad, said, Climate change affects all the three aspects of food security; availability, access and absorption. When production decreases. Climate change hits poor the most. They don't have income to buy the food, so their access to it is affected. This, in turn has an impact on health and Elevated atmospheric CO_2 concentrations, global warming and extreme weather events will impact food production, altering the current level of suitability of regions for specific crops. Changes in rainfall patterns and increases in temperature and carbon dioxide levels are likely to have major implications for agricultural productivity, with positive impacts in some regions and negative impacts in others. Elevated CO_2 can improve photosynthetic efficiency, Thus increasing the yield of C3 crops and decreasing water consumption through decreases in stomatal conductance in C3 and C4 crops. Conversely, variations in temperature, precipitation and ozone concentrations may affect plant growth and development through increases in abiotic stress. Such changes will have important impacts in the quantity and quality of agricultural production, in terms of food security and the welfare of a growing global population.

Maize (*Zea mays* L.) is a major food source for the world and is a high-yield commodity crop, with an average harvested area of 157 million hectares and production of 781 mega tonnes from 2000 to 2014; it is a vital source of food security in many developing countries in Latin America and Sub-Saharan Africa. Furthermore, it serves as forage for the production of biogas. Maize originated in the Mexican Highlands and spread around the world after the colonization of America. Mexico remains one of the main producers, with an average yearly production of 14 mega tonnes from 1961 to 2014, ranked fourth in the world. Maize can be produced in an extended range of conditions, from and under precipitation levels from 200 mm to 2000 mm. Though a variety of abiotic (soil, climate) and biotic (diseases, plagues) stresses affect maize, its main constraints are currently climatic factors and physical characteristics related to soil fertility. To date, several studies have addressed the possible impacts of climate change on maize, mostly at the regional level and focusing on changes in productivity. Some studies have indicated that temperature increases have a negative effect on maize yield, whereas CO_2 increases could be beneficial for changes in water availability. However, the level of uncertainty in the CO_2 results has been consistently high in all research studies. This crop is extremely susceptible to drought during the flowering stage, during which the quality of the seed is reduced. Maize drought stress could result in yield losses of nearly 50% in southern Africa. In general, studies have reported a negative impact on maize production that is attributable to increasing temperatures and reduced precipitation[9]. Several institutions around the world have released maize varieties resistant to drought or heat stress to reduce vulnerability affects absorption. According to him, climate change has about 4-9% impact on agriculture each year. As agriculture contributes 15 % to india's GDP, climate change presumably causes about 1.5percent loss in GDP. Climate change poses a formidable threat to sustainable development of south Asia, as the region is vulnerable to impacts of climate change due to high population density, poverty, and lack of resources for adaptation (Ahmed and Suphachalasai 2014) [2]. Despite rapid urbanisation, the majority of the Indian population is still rural and dependent on agriculture for their livelihood (Hijoka *et al*. 2014) [107] and will remain vulnerable to climate shocks for the foreseeable future. Global warming has occurred across the globe especially over south asia over the twentieth century and into twenty –first century with more frequent incidences of temperature extremes (Lal 2005; Lal 2011; Hijioka *et al.* 2014) [126, 125, 107]. Extreme heat stress during the crop reproductive period can be critical for crop productivity, and hence projected changes in the frequency and severity of extreme climatic events are expected to negatively impact crop yields and global food production (knox *et al.* 2012; Gourdji *et al.* 2013; deryng *et al.* 2014) [115, 93, 63] Each rise in mean temperature by 1degree is predicted to cause huge yield losses in india, and farmers are projected to lose up to US$20 billion each year (FAO 2008; swaminathan and Kesavan 2012) [78, 115]

Maize (zea mays) production has been growing rapidly in india overs the last decades with an annual harvested area reaching 12 million ha recently (Faostat 2013) [78]. The growth is response to surge in regional maize demand, driven by economic growth, changing diets, and the rapidly growing poultry sector, where maize constitutes about 65%of the poultry ration (Shiferaw *et al.* 2011) [161] Maize is now grown by millions of smallholder farmers in the region almost all year round mostly under sub-tropical rainfed lowland conditions.

Impacts of Climate Change on Maize

1. Drought Stress

2. Heat Stress.

Impact of climate change with respect to Maize has been immense but more severe is heatstress and drought. Maize has been vulnerable to heat stress during the reproductive stage (Rattalino Edrerira et at 2011; Cairrns *et al* 2012; Mayer *et al.* 2014; Rezaei *et al.* 2015) [149, 134, 50], and it is reported that each degree increase in day where the temperature exceeds 30 degree reduces the final yield of maize by 1% under favourable growing conditions and by 1.7%under drought –sressed (Lobell *et al.* 2011b) [146]. Most of the sub-tropical maize growing areas in india are highly vulnerable to high temperature stress, particularly during the premonsoon season when maize is prone to severe heat sress during anthesis and early grain –filling stages (Prassana 2011)

Erect of drought on maize

Drought stress is seriously affecting the maize crop resultantly hindering the productivity like other crops being drought sensitive crop, maize is affected at each and every stage of growth and development by lesser moisture availability. Prevalence of drought at seedling stage causes poor crop stand and under extreme conditions can result in complete failure of seedling establishment (Zeid and Nermin 2011). Shutting down of plant metabolism followed by plant death due to stomatal closure and inhibited gaseous exchange occurs in response to prolonged moderate drought stress (jaleel *et al.* 2007) [108]. In case of maize reproductive growth stage is comparatively more sensitive to drought stress and under severe drought prevalence barren ear production might result (Yang *et al*. 2004) [181]. Global importance of maize and side effects of drought triggered the breeders to develop drought tolerance maize germplasm. Drought responsive traits and adaptive mechanisms must be known for the development of drought tolerant maize stock.

1. Effects on crop stand establishment
2. Effects on Growth and development.
3. Effects on Reproductive Growth stages
3.1. Pollen development
3.2. Silk development
3.3. Pollination
3.4. Embryo development
3.5. Endosperm Development
3.6. Grain or Kernel Development.

Effects on crop stand establishment

Crop stand establishment comprised of germination, emergence and seedling establishment, Concepts of germination and emergence prevailed under laboratory conditions and field respectively. Crop establishment accomplished up to development of 7^{th} or 8^{th} leaf. These early growth stages are critical regarding drought stress. Always there are prominent differences among different levels of water treatments in maize regarding their effects at early growth stages. Proper seed germination is dependent on availability of appropriate moisture contents for metabolic activation to breakdown the dormancy or to convert stored food into consumable form. Crop density or number of emerged seeds, mean time for emergence and synchronization of emergence are characteristic features which determined the efficacy of seedling establishment (Fincgh-Savage 1995). Crop survival, growth and development are determined by seedling establishment (Hadas 2004) [94]. Drought stress reduces the germination potential of maize seeds by reducing their viability Severity of drought stress is directly linked with poor imbibitions, germination and seedling establishment in maize (Achakzai. 2009) [4]. Germination potential, germination rate and seedling growth are studied traits under drought stress because these traits are direct representative of crop establishment and are badly affected by drought stress (Delachiave and pinho 2003) [69]. Maize grain is greater than other cereals like wheat, rice and barley therefore, water requirement is greater for maintainence for osmotic potential and conversion of stored food into consumable form for poor germination (Gharoobi *et al.* 2012) [86]. Water absorption, imbibitions and metabolic enzymatic activation are hindered under limited water availability which reduces the maize grain germination. After germination water deficiency significantly reduced the plumule and radical growth which resulted in unusual seedling growth (Gharoobi *et al.* 2012) [86].

Hydro priming and osmo priming of maize seed result in improved seed germination by regulation of enzymatic activity to break the dormancy which clearly highlights the importance of water availability for exploitation of full germination potential (Janmohammadi *et al.* 2008) [109].

Effects on growth and development

Proper growth and development of crop plant s is important for establishment of normal plant structure that carry out all physiological and metabolic process and give potential yield. Drought stress seriously hindered the growth and development of maize. Growth and development comprised of numerous component parameters which are estimated by different traits like, plant height, leaf area, structural and functional characters of root, plant biomass fresh weight, plant dry weight and stem diameter. Plant height, stem diameter, plant biomass and leaf area are reduced under drought stress (Khan *et al*. 2001; Zha *et al*. 2006) [117, 187] temperature under limited water availability (Jones 1992) [110]. Growth is described as increase in size of plant which is directly associated within increase in number of cells and cell size. Meristematic tissues are involved in active elongation of plant by active cell division Cell division and cell size are reduced by reduction in water potential of cell's which causes the reduction in plant growth Light intercept ion is reduced after reduction of leaf area. Less interception of solar radiation s causes the reduction in biomass production (Delfine *et al*. 2001) [65]. Besides light interception, stomatal activity is also responsible for lower biomass product ion (Delfine *et al*. 2001) [65]. Rise in leaf temperature under drought stress, inhibits the enzymatic activity and reduces photosynthesis (Chaves *et al*. 2002) [56] Photosynthetic machinery is inactivated by increase in leaf temperapture above threshold temperature whichis30°c (Crafts-Brandner and Salvucc 2002) [61] reduced transpiration and its homeostatic effects are the cause often rise in temperature leaf Stomatal closure has protective role in saving the water loss and increasing water

use efficiency under mild drought stress but under severe drought stress stomatal closure becomes inevitable evil (Chaves *et al*. 2009) [59]. Kinases protein family and cyclin-dependent kinases (CDKs) are involved in the active progression of cell cycle. CDK activity is reduced under water deficit conditions which increased the duration of cell division and decreases the number of cell divisions per unit time that ultimately reduces the growth of leaves and plant (Granier *et al*. 2000) [165]. Cell elongation is found to be reduced across all point son leaf. Common regulatory pathway is involved in cell division and cell elongation (Tardieu *et al*. 2000) [54]. Drought stress increases the leaf to stem ratio which is indication of high level of growth retardation in stems than leaves (Hajibabaee *et al*. 2012) [97]. Reduced water potential in roots interrupts the optimal water supply to the elongating cells and resultantly cell elongation is reduced. Water potential less than − 10.0 Bars causes the reduction in leaf growth (Tan guilig *et al*. 1987). Maize is C4 plant and it is reported in C4 plant s that intercellular spaces and chloroplast position s are misplace d by drought stress resultantly CO2 diffusion and light penetration are disturbed followed by decreased photosynthetic activity (Flexas *et al*. 2004) [80]. Photorespiration and Mahler's reaction act as alternative electron sinks under drought stress (Ghannoum 2009) [90]. Mahler's reaction is involved in generation of reactive oxygen species and develops oxidative stress under drought stress. Oxygen molecule is converted into superoxide as a result of direct reduction reaction in Photosystem-I (Haupt-Herting and Fock 2002) [101]. Photosynthetic metabolism is reduced by reduction reaction of carbon substrate. Carboxylation activity of RUBISCO, regeneration of RuBP and ATP are reduced by inhibited CO2 concentration in the leaves under drought stress (Tezara *et al*. 1999) [167]. CO2 diffusion through mesophyll is reduced due to change in carbon metabolism and leaf photochemistry under drought stress. Leaf biochemistry, membrane permeability (aquaporin activity), leaf shrinkage, alterations in intercellular spaces, intercellular structure, internal diffusion and internal conductance are altered under drought stress which results in reduction of CO2 diffusion through mesophyll (Lawlor and Cornic 2002; Chaves *et al*. 2009) [124, 57] Roots of maize plant becomes elongated under mild drought stress to explore the more soil foils for more water uptake whereas under severe drought stress root length is reduced. Root density volume and number of roots are reduced under mild and severe drought stress (Nejad *et al*. 2010) [138].

Requirement of photosynthates and energy is reduced in leaves due to reduced leaf area by leaf rolling or curling under mild drought stress. Photosynthetic assimilates from leaves are directed toward roots for their elongation to increase the water uptake (Taiz and Zeger 2006) [168]. Roots act as primary sensor of water deficiency in soil and transduce signals to the aerial parts to modulate the growth and development. Signal from roots to the aerial parts are transduced through chemical and hydraulic vector s (Davies *et al*. 1994) [62]. Decreased water and nutrient uptake increase the pH of xylem (reduction of negative or positive ions) which transduces ABA-mediated signals to the leaves for preventing water loss by stomatal closure (Bahrun *et al*. 2002) [31]. Reduction in root grow th under drought stress is also associated with reduced cell division and cell elongation. Microtubules are critical for cell division and cell elongation because these microtubules are involved in cellular morphogenesis, embryo development, organogenesis stomatal conductance and organ twisting (Steinborn *et al*. 2002; Whittington *et al*. 2001; Marcu s *et al*. 2001; Thitam adee *et al*. 2002) [162, 171, 135, 170]. Reduced root turgor under dehydrated condition s, increases ABA accumulation and plasmolysis. Plasmolysis seriously damages the microtubule skeleton and cellular geometry (Pollock and Pickett-H eaps 2005). Disrupted microtubules in roots induce the ABA accumulation by increasing ABA biosynthesis. Interactions between microtubules, cell wall, plasma membrane and ABA biosynthesis are reported under osmotic stress (Lu *et al.* 2007).

Effects on reproductive growth stages

Drought has adverse effects on maize life cycle; particularly reproductive growth phase is most susceptible to drought stress. Translocation of photosynthetic assimilates to the reproductive parts rather than roots for their extensive elongation is most probable reason for more susceptibility of maize plant during reproductive growth stage under drought stress (Setter *et al*. 2001; Taiz and Zeiger 2006) [168, 156].

Sequential effects of drought stress on reproductive growth stage s of maize Pollen and silk development, pollination, embryo development, endosperm development and kernel development are the different component phases of reproductive growth stage which are severely threatened by drought stress.

Effect on pollen development

Pollens are affected by drought stress in different ways. Pollen mortality occurred due to dehydration as moisture of pollen is lost due to drying condition s (Aylor 2004). Settling speed, poll en viability, specific gravity, pollen shape and dispersal are seriously affected in de hydrated pollens (Aylor 2002). Increased ABA accumulation and reduced invertase activity are the main reason s for poll en sterility under drought stress (Saini and Westgate 2000) [159]. Con version of sucrose to hexoses is imp aired by reduced invertase activity (Sheoran and Saini 1996). Pollens of maize were studied under drought and high temperature stresses which showed that pollen weight, pollen viability, poll en size, pollen tube length and pollen moisture contents were affected by these stresse's. Maize pollens are of large size as compared to other angiosperms and have relatively higher moisture contents. Pollen viability is reduced greatly if pollen moisture contents are reduced below 0.4 g per gram of pollens (Buitink *et al*. 1996) [46]. Pollens absorb moisture from hydrated silk to initiate proper germination so, pollen germination is reduced in case of dehydrated silk under drought stress (Heslop-Harrison 1979) [99]. Starch and certain osmolytes are present in the pollens which protect them from losing viability. Drought stress reduced the accumulation of starch in pollens during pollen development which rendered them non-functional (Schoper *et al*. 1987) [155]. Upregulation of galactinol and vacuole invertase genes in pollen under drought stress showed that these protect the pollens through osmoprotection and prevent the loss of viability (Taji *et al*. 2002) [171]. Gene expression is changed in such a way that cell wall structure and synthesis is impaired which results in loss of poll en viability under drought stress (Zhuang *et al*. 2007) [188]. Severe drought stress at tasseling stage reduce the yield by affecting the number of kernels per row, number of kernel rows, harvest index, number of kernel s per cob and grain yield per plant (Anjum *et al*. 2011) [10]. Increase in ABA accumulation up to 0.5 µ M favor the pollen germinat ion and pollen tube elongation but further increase in ABA contents significantly reduces the pollen germination and pollen tube elongation (Zhang *et al*. 2006)

Effect on silk development

After fertilization, elongation of silks stops and desiccation starts. Under drought stress, desiccation of silks starts earlier and pollen tube becomes unable to reach the ovary resultantly no fertilization occurred. Fertilization failure occurs because of earlier silks desiccati on du e to drought conditions and ear bareness becomes the fate (Dass *et al*. 2001) [64]. So, assimi late partitioning towards the silk and hydration of silks are of prime importance for higher grain yield.

Effect on pollination

Glucose contents in the pedicle of ovary are reduced due to IVR2 (soluble invertase) reduct ion during pre and post pollination under drought stress (Qin *et al*. 2004) [145]. Starch contents of the floral parts are reduced under drought stress due to impaired activity of the enzymes involved in starch metabolism (Zinselmeier *et al*. 2002). [186] Pollination process is disturbed in following ways by drought stress; (a) silk becomes dried under dehydrated conditions and no more supportive for pollen tube development (Nielsen 2002) [138], (b) pollen shedding occurs before silking which causes increase in anthes is silking interval (Nielsen 2002) [139], (c) silk elongation rate is reduced (Lauer 2012) [129], (d) silk becomes non-receptive for pollen grains under dehydrated condition s along with low humidity (Nielsen 2005a, b) [140]. So, the pollination process is badly affected by drought stress in maize causing low productivity at the end.

Effect on embryo development

Embryonic development is very susceptible to drought stress. During early embryonic develo pment, embryo abortion occurs due to drought or heat stress (Setter *et al*. 2011). Drought stress prior to fertilization can cause embryo abortion (Andersen *et al*. 2002) [9] Embryo sac development is impaired due to imposition of drought stress during megaspore mother cell formati on and resultantly 80– 90 % yield losses are reported (Moss and Downe 1971) [137]. Insufficient provision of photosynthetic assimilates and sugar substrate s to developing embryo cause their abortion (Feng *et al*. 2011) [76]. Soluble invertases (Ivr2) and cell wall associated inver tases are responsible for the provision of hexose to the developing embryos. These invertases are suppressed under drought stress causing check to supply of sugars and assimilate to embryo resulting embryo abortion (Andersen *et al*. 2002; Feng *et al*. 2011) [9, 76]. Sucrose (substrate for invertase) to hexose ratio is very important for normal embryo development which is imp aired during drought stress. Cell wall associated invertases and sugars are involved in signa ling pathways and theses signaling pathways are affected by disturbance in expression of invertases and sugars (Kakumanu *et al*. 2012) [116]. Exogenous application of nutrients at reprod uctive stages rescue the 80 % embryos which proves that assimilate translocation is major reason for embryo abortion relative to lower water potential which causes comparatively less damage (Boyle *et al*. 1991) [136]. Leaves upload sucrose in phloem then it reach to pedicle where invertases hydrolyse sucrose into glucose and sucrose. These hexoses are used for kernel d evelopment

(Cheng *et al*. 1996) [58] and starch biosynthesis which participate in ovary development. ABA accumulation triggers the embryo abortion under drought stress (Setter *et al*. 2001) [156]. So, embryo development is very susceptible reproductive growth stage to drought stre ss which is affected by different ways.

Effect on endosperm

Prevalence of drought stress after fertilization, suppresses the cell elongation and multiplication of organelles causing reduction in final endosperm volume. Comparative evaluation show ed that end reduplication is less affected by drought relative to mitotic cell division (Artlip *et al*. 1995) [19].

Effect on grain development

Kernel development is very important phase as for as productivity is concerned and comprised of following component stages; blister stage, soft dough stage, milking stage, hard dough stage and dent stage. High moisture con tents are needed during blister stage for grain filling and drought stress at this stage results in poor quality kernel s. Moisture requirement during soft dough, milking and hard dough stages is higher enough that drought stress at these stage s can reduce the kernel quality and yield. Drought stress du ring hard dough stage causes the premature hanging of the cobs. Water requirement of dent stage is lower relative to pre-dent stage s of kernel development but drought stress at this stage still can cause potential loss in yield and quality (Pannar 2012) [142].

Kernel development in maize is comprised of three major stages; (a) lag phase; sink capacity is developed, water contents increase and biomass accumulation reduces (Saini and West gate 2000) [159], (b) effective grain filling stage or linear phase; maximum biomass accumulation occurs in this stage and kernel size is determined (Westgate *et al*. 2004) [160], (c) physiological maturity; maximum dry weight is gained and later on grain enter s in quiescent phase (Saini and West gate 2000) [159].

Sink capacity and source strength interact wi th each other for grain filling. Difference s in grain weight are due to difference in source sink ratio. Source strength is determined by photosynthesis and carbohydrate assimilation whereas, sink capacity is determined by sink’s activity (Westgate *et al*. 2004; Yang *et al*. 2004) [181, 160]. Drought stress reduces the photosynthes is and translocation of photosynthetic assimilates followed by reduced grain filling. Source strength and sink capacity are reduced by drought stress in maize. Grain size reduction is caused by reduced remobilization of photosynthetic assimilates (Yadav *et al*. 2004) [182]. Grain filling is also reduced due to decreased activity of sucrose and starch synthesizing enzymes under drought stress (Anjum *et al*. 2011b) [14]. Numbers of kernel s are determined during pre-anthesis stages whereas; kernel weight is determined at post-anthesis stage s. Drought stress during post-anthesis stage s is responsible for kernel weight reduction (Oveysi *et al*. 2010) [141]. Inter action of water and biomass during kernel development are the deter minants of final kernel volume. Water contents of the kernel are increased during early developmental stages of kernel and later on water contents decrease followed by increase in biomass accumulation. Biomass accumulation is dependent on source strength and sink’s capacity which are seriously reduced by drought stress so final kernel volume is reduced by drought stress (Gambín *et al*. 2006) [82]. Reduced water potential and kernel water uptake squeeze the duration of kernel filling resultantly kernel size is reduced (Brenda *et al*. 2007). It is reported that drought stress during, kernel development is responsible for 20– 30 % yield losses which are mainly due to under sized kernel s (Heinigre 2000) [100]. Another report mentioned that drought prevalence during kernel development can cause 2.5– 5.8 % yield losses on daily basis (Lauer 2003) [127].

Impact of heat stress on maize

High temperature stress causes adverse effect on plant development, physiological process and grain yield. Heat stress as one of major consequences leads to oxidative stress due to production of excess reactive oxygen species (ROS). High temperature hinder plant growth and development so plant need to continuously struggle for survival (Hasanuzzaman *et al*. 2013) [105]. Under heat stress condition plants changes physical changes and creating signals for alter the different metabolism to cope high temperature. Crop alter their metabolism through giving compatible solute that responsible to organize protein, cellular structure, keep and maintain cell turgor, changes the antioxidant system to re-establish the cellular redoxequilibrium and homeostasis (Valliyondanand Nguyen 2006; Munns and Tester 2008) [133]. Heatstress changes the expression of gene at molecular level (Shinozaki and Yamaguchi-Shinozaki 2007; Collins *et al*. 2008) [160, 54]. Osmo protectants, detoxifying enzymes, transporters and regulatory proteins controlled gene expression is depend upon heatstress condition (Semenov and Halford 2009; Krasensky and Jonak 2012) [114]. Heat stress depends upon three factor and they are duration of temperature, degree of temperature and nature of crop. To survival and growth of plant in heat stress condition one mechanisms activated which lead to cellular dead or injury within few minutes which responsible for catastrophic collapse of cellular organization (Ahuja *et al*. 2010) [115]. Different plant stages such as germination, growth, development, fertilization and reproduction influence by heatstress (Mittler and Blumward 2010). Heat stress differentially affect the protein stability, membrane, RNA species and structure of cytoskeleton and alters the efficiency of enzymatic reaction in the cell for which responsible for alter and imbalance metabolic and physiological process (Ruelland and Zachowski 2010) [148]. Heat stress responsible for loss of cell water content due to that cell size and growth is decreases (Rodriguez *et al*. 2005). Relative growth rate (PGR) in maize and millet reduced due to reduction in net assimilation rate (NAR) under heat stress (Wahid 2007) [176]. Leaf firing tassel blast, leaf senescence, inhibition of root and shoot, changes colour of fruit and damage sign in fruit were important morphological sign under heat stress condition (Rodriguez *et al*. 2005). Heat stress causes reduction of plant growth duration due to increases growth rate and ultimate shorter life cycle of crop. Temperature (>1 -2°C) than the normal lead to reduction in grain filling duration and negatively affect yield and yield attributing traits (Zhang *et al*. 2006). Plant growth and development stages are susceptible to heat stress. In comparison to vegetative stages of crop reproductive stage is most susceptible to heat stress and few degrees increases in temperature at the time of flowering causes entire loss of grain cycle (Lobell *et al*. 2011) [109]. Plant species showed significant variation in decreases in floral bud and flower abortion under heat stress conditions (Demirevskyakepova *et al*. 2005). In heat stress conditions leads to impaired cell division in both male and female organs, pollen tube germination and growth, ovule viability, anomaly in position of stigmatic and style, number of pollen per silk during fertilization, poor growth endosperm, proembryo and barren embryo. These mechanisms are also responsible for production of sterile plant due to absent in flower or fruit at reproductive stage (Yun-Ying *et al*. 2008) [183]. Under stressful environmental condition genetic improvement can be achieved by selection of primary traits such as yield and secondary trait related to improved yield potential secondary traits more important for genetic improvement for maize population under abiotic stress condition (Betran *et al*. 2003).

Anthesis siliking interval (ASI)
Chapman *et al*. (1997b) reported that most of high yielding plant in most of environment had short ASI and Higher ear per plant (EPP)particularly in drought environments. Boonpradub and Senthong (2001) [37] reported that ASI was negatively correlated with kernel yield only for dryregime. Betran *et al*. (2003) reported that shorter ASI were associated with higher grain yields. Difference in grain yield under drought imposed were strongly associated with reduces ASI. When high difference between anthesis and tassling in maize leads to responsible for longer anthesis silking interval under high temperature condition (Cicchino *et al*. 2010) [59].

Tassel blast
Tassel blast was found to be negatively and highly significantly correlated with grain yield and positive significant association between leaf firing in maize (Hussain *et al*. 2006) [104].

Leaf firing
Chen *et al*. (2010) reported that under high temperature stress condition leaf firing reduces photosynthetic apparatus. Significant reduction in yield per plant with increase in percent leaf firing and days to flowering and reduction in chlorophyll fluorescence and number of tassel branches in heatstress were also reported by Bai (2003) [34].

Silk receptivity (%)
Kernel number per cob was control by number of pollen available at time of silking in maize.
Pollen densities less than 3000 pollen grain per silk required for optimum number of kernel production in maize. So minimum number of pollen density per exposed silk is required for maximum grain yield (Westgate *et al*. 2003) [175]. Maize kernel set determine by silk elongation pattern and duration of silk receptivity. Silk elongation and senescence variation lead to determine grain yield (Anderson *et al*. 2004) [17]. Campos *et al*. (2004) reported that grain yield performance in multi environmental condition under drought condition trough increase yield potential and kernel set rapid silk exertion and reduced barrenness through at lower rate than under optimal condition help the selection heat stress tolerance genotypes in heat stress breeding.

Leaf senescence (%)
Lobell *et al*. (2012) reported senescence as limiting factor for grain filling and grain yields under heat stress. Kamara *et al*. (2003) concluded leaf dead score did not significantly correlated with grain yield but were highly correlated with LAI indicating the importance of green area for which is related to chlorophyll content and responsible for photosynthesis and help in maintains of high grain yield under drought. Delayed senescence which means stay green nature of plant is secondary character importance and relatively high leaf chlorophyll during late grain filling in stress (Zaidi *et al*. 2004) [184].

Crop maturity days
Grain filling duration time between heading date to physiological maturity and rate no significant association with grain yield in most of cases. But under water deficient condition during maturities it was associated with increases yield in cereals (Talbert *et al*. 2001) [163].

Chlorophyll content
Grain yield was significantly correlated with chlorophyll content and EPP under severe drought stress condition (Betran *et al.* 2003a). The association between leaf injury and low chlorophyll content in maize plants (Liu and Huang 2000).

Plant height
Reduction of rate of growth of first internode of plan under the heat stress condition which initial step of plant height development in maize and that determine plant height in maturity (Weaich *et al*.1996) [179].

Number of kernel per ear
under heat stress condition in corn kernel number loss due to kernel abortion due to pollen viability and pollination dynamics which ultimate limit the crop production (Cicchino *et al*. 2010b) [61].

Grain yield
Maize inbred lines reduced grain yield up to 70% in high temperature condition (Khodarahmpour *et al*. 2011) [111]. Lower grain yield was associated with pollen viability and fertilization under high temperature (Rowhani *et al*. 2011) [147]. Grain filling as one of most sensitive stage of corn under heat stress (Thompson 1986) [169]. Grain yield and biomass production was affects by heat stress but mechanism was varying with crop stage. Stress in pre-anthesis stress leading to barrenness in plants, while absorption of fertilized structure and reduced ear growth rate lead to reduction in kernel number and ultimate affect crop yield (Cicchino *et al* 2010a.) [60].

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